CGS NPDES
Comment
#005

ENERGY NORTHWEST

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ENERGY FACILITY SITE
EVALUATION COUNCIL

Mr. Stephen Posner
EFSEC Compliance Manager
Energy Facility Site Evaluation Council
Utilities and Transportation Commission
P.O. Box 43172
Olympia, WA 98504-3172

Dear Mr. Posner:

Subject: **COLUMBIA GENERATING STATION (COLUMBIA) NATIONAL POLLUTANT DISCHARGE ELIMINATION SYSTEM (NPDES) PERMIT REISSUE, INTAKE STRUCTURE COMMENTS**

References: 1) Letter, GI2-14-019, dated February 3, 2014, J La Spina (EFSEC) to M Reddemann, "Columbia Generating Station NPDES Permit Renewal"

2) Norlund, B. July 31, 2013. Entrainment and Impingement Potential for Salmonids at the Columbia Generating Station (CGS) Intake Screens. Memorandum for Hydro Division Files. National Marine Fisheries Service, Portland, Oregon.

3) NMFS. August 6, 2013. Notice of concern regarding pre-public review draft of Energy Facility Site Evaluation Council (EFSEC)/Washington Department of Ecology (WDOE)'s proposed Columbia Generating Station (CGS) National Pollutant Discharge Elimination System (NPDES) Permit No. WA-002515-1 and accompanying Fact Sheet. [With two attachments: B. Nordlund, July 31, 2013 and August 7, 2013]

4) Norlund, B. August 7, 2013. Columbia Generating Station (CGS) – Intake Screens Assessment and Recommendations for Modifications. Memorandum for Hydro Division Files. National Marine Fisheries Service, Portland, Oregon.

5) EPA. August 8, 2013. U.S. Environmental Protection Agency's Comments on *Preliminary* Draft National Pollutant Discharge Elimination System (NPDES) Permit for the Columbia Generation Station, NPDES No. WA0025151. Letter from M. J. Lidgard, EPA to J. La Spina, Washington Energy Facility Site Evaluation Council.

6) NMFS. December 12, 2013. Letter Re: Columbia Generating Station Cooling Water Intake Screen NMFS Consultation No. (I/NWR/2011/05286) [With attachments: B. Nordlund, December 12, 2013]

7) Norlund, B. December 12, 2013. Review of recent info regarding Columbia Generating Station. Memorandum for Richie Graves. National Marine Fisheries Service, Portland, Oregon.

The Energy Facility Site Evaluation Council (EFSEC) has made a tentative determination to reissue the National Pollutant Discharge Elimination System (NPDES) permit No. WA-002515-1 for Energy Northwest's (EN) Columbia Generating Station (Columbia) and is seeking public comment (Reference 1). EN thanks EFSEC for their diligent efforts to reissue the permit. As you are aware, EN submitted an application for renewal of the NPDES permit in November 2010, and a supplemental application in December 2013. We have reviewed the draft permit and fact sheet for accuracy and completeness and provided input throughout the process to EFSEC staff. We maintain that, based on the current regulations and NPDES permitting requirements, Columbia meets the regulatory requirements under the NPDES permitting process.

EN has reviewed the comments provided by other federal agencies as part of this review process (References 2-7 above). We acknowledge these agencies had questions that required attention and further discussion. In November 2013, EN technical staff met with the National Marine Fisheries Service (NMFS) and the Environmental Protection Agency (EPA) on conference, and began a dialog related to intake structure and listed species concerns as described in the comment letters. While NMFS has continued to provide comments throughout this process, we have noted a number of inaccuracies in comment letters and memoranda related to the design, operation and maintenance of Columbia's intake structure, and unverified and unsupported conclusions regarding potential impacts to salmonids.

In response to NMFS comment letters and memoranda authored by Mr. Nordland, EN enlisted the services of Dr. Charles Coutant, PhD to evaluate Columbia's intake structure design, comments submitted by NMFS, and relevant scientific studies and literature. Dr. Coutant's comments were summarized in a paper originally provided to NMFS at our November 2013 meeting, and recently revised for this comment submission. While the NMFS letters and memoranda identify concerns related to Endangered Species Act (ESA) listed species, we believe Dr. Coutant's research into these questions provide objective evidence that counter many of NMFS claims. EN is submitting as Attachment 1 Dr. Coutant's paper, *Why Cylindrical Screens in Flowing Water Impinge and Entrain Few Fish and Its Importance for The Columbia Generating Station's Intake,* as part of our NPDES comment response.

Further, EN is submitting a specific summary and response to the NMFS December 12, 2013 memorandum (Reference 7 above). This response also includes a review of the technical studies and references NMFS used as their basis for the December 12, 2013 memorandum. This document is submitted as Attachment 2.

 COLUMBIA GENERATING STATION (COLUMBIA) NATIONAL POLLUTANT DISCHARGE ELIMINATION SYSTEM (NPDES) PERMIT REISSUE, INTAKE STRUCTURE COMMENTS

EN appreciates the opportunity to provide comments. This information is being submitted to provide clarification, expand on the opinions provided by NMFS, and broaden the scientific information upon which regulatory decisions will be made. EN recognizes and appreciates the exceptional support of EFSEC and the Washington State Department of Ecology in preparing the draft permit and fact sheet, and we look forward to the Council approving the new NPDES permit for Columbia. If you have questions or desire further information, please contact Shannon Khounnala at (509) 377-8639.

Respectfully,

DK Atkinson
Vice President, Employee Development/Corporate Services

Attachments: 1) Dr. Charles Coutant, April 2014. *Why Cylindrical Screens in Flowing Water Impinge and Entrain Few Fish and Its Importance for The Columbia Generating Station's Intake.*

2) Dr. Charles Coutant, April 2014. *Comments on NMFS letter of December 12, 2013 to Shannon Khounnala of Energy Northwest by Michael P. Tehan of NMFS, with its Attached Memo* and *Appendix A. Review of Fish Screen Evaluation References Cited by NMFS: Relevance to The Columbia Generating Station In-River Intake Screens.*

cc: Michael Tehan, NMFS
Rich Domingue, NMFS
Karen Burgess, EPA
Fred Lyon, NRC
Bill Moore, Ecology
Dr. Charles Coutant
Mike Elsen, DOE

Why Cylindrical Screens in Flowing Water Impinge and Entrain Few Fish and Its Importance for The Columbia Generating Station's Intake

Discussion Paper
for
Meeting Between Energy Northwest and National Marine Fisheries Service
Portland, Oregon, November 13, 2013

Revised for Washington's Energy Facility Site Evaluation Council and Department of Ecology and U.S. Environmental Protection Agency
April 9, 2014

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Impingement and entrainment of aquatic organisms from source waters are important concerns for water withdrawals. Cooling water from thermal power plants and diversions for agricultural irrigation are often large enough that significant numbers of organisms might be affected. Traditionally, these risks have been minimized by design criteria for intake screens that have focused on pore or slot sizes and approach or through-screen water velocities (Bell 1990, EPA 2013, NMFS 2011). Pore or slot sizes are intended to be small enough that target organisms cannot fit through. Approach and through-screen velocities are intended to be low enough that the target organisms can swim away from the screen openings despite the inflow. These criteria assume that physical and behavioral characteristics at or near the screen openings are the predominant factors determining whether an organism becomes stuck on the screen (impingement) or passes through (entrainment). The National Marine Fisheries Service, Portland District (NMFS), has mandated that circular screen-face openings where anadromous fish are present "must not exceed 3/32 inch [2.4 mm] in diameter" and the approach velocity at an intake screen "must not exceed 0.40 ft/s [0.12 m/s] for active screens, or 0.20 ft/s [0.06 m/s] for passive screens" (NMFS 2011, Section 11, pages 89 and 94, respectively). These criteria were developed for rotating drum screens, vertical screens, and inclined screens (NMFS 2011, page 89), but not specifically for cylindrical screens of the type and placement used at Energy Northwest's Columbia Generating Station (CGS) for nearly 30 years.

Analysis of relevant scientific literature indicates that the assumption that pore size and approach velocity are most important is not appropriate for cylindrical screens oriented parallel to water movement in flowing water, especially for downstream-migrating juvenile salmon. Early assessments of cylindrical screens indicated that entrainment of fish eggs and larvae by the screens appeared to be less than could be explained by physical exclusion alone (Enercon 2010). We are now beginning to understand why, through recent laboratory studies of cylindrical screens oriented parallel with flow in flowing water, basic scientific research on fluid dynamics of fish perception, and field studies of fish encountering obstacles. The fluid dynamics of a cylindrical screen in flowing water coupled with a fish's size-dependent ability to sense changes in the fluid dynamics of its surroundings (enhanced by its own swimming motions) combine to nearly ensure low vulnerability to a porous cylindrical screen of the type and placement used successfully at CGS since the early 1980s.

This presentation reviews the pertinent scientific information on the fluid dynamics of both a typical cylindrical screen in flowing water and a swimming fish, and points out the key sensory and behavioral features of fish, including juvenile salmon, that foster safe passage around the screen. The emphasis is on functional principles for fish protection derived from detailed fluid dynamics and fish-behavior studies. This basic discussion is followed by specific application to concerns raised by NMFS to the cylindrical screens used by the Columbia Generating Station (CGS) on the Columbia River for make-up water for its cooling towers.

Cylindrical Screens

Cylindrical screens designed for flowing water are typically bullet shaped, with solid cones at the upstream and downstream ends, a metal frame at the upstream and downstream ends and in the center that forms the cylinder, and screen material between the upstream and downstream frames (nose cones) and the central frame (**Figure 1**). Water enters the screen perpendicular to ambient water flow. Water is withdrawn from the central cavity of the cylinder, typically through a single pipe at right angles to the orientation of the cylinder. The screen material has been formed of perforated plate (Alam et al. 1974; NRC 2011) or, more recently, wedgewire (NAI and ASA 2011a). The screen assembly typically includes an inner system of baffles or pores to provide an even distribution of water velocities through the outer screen. Pore sizes for perforated plate screens (as for other types of screens) have varied, but historically have often been 3/8 (0.4) inches (1 cm) in diameter, as at the Columbia Generating Station (the NMFS criteria for pore size and approach velocity were initiated in 1990, after CGS was operational). Slot sizes of 2-9 mm (0.08-0.35 in) have been used for wedgewire screens (NAI and ASA 2011a). In environments where screen clogging by debris or aquatic vegetation has been a problem, cleaning systems consisting of air blasts or external brushes have been used. At many sites with low debris loads and high ambient water velocities, including the Columbia Generating Station, no cleaning system has been needed.

The hydrodynamics of flow around an obstacle such as the nose cone of a cylindrical screen are well understood (Liao 2007). The velocity of the uniform flow upstream of the obstacle is rapidly reduced by the presence of the obstacle (**Figure 1**). There is a zone of low to zero velocity immediately upstream of the obstacle (the null velocity point). This velocity change initiates the well known "bow wave." Flow lines then part, are deflected lateral to the obstacle and reform, often as eddies and a sequence of opposing turbulent eddies (a Kármán street) downstream of the obstacle (**Figures 1 and 2**). Water between the lateral arms of the bow wave and the cylinder can enter the side of the cylinder, as shown in Figure 1 (organisms in the water do not necessarily follow the water flow into the screen, as discussed below). Although usually portrayed in two dimensions, the hydrodynamic effects are three dimensional at a cylinder suspended in a water column.

Studies of Early Fish Life Stages – Hudson River

Entrainment of early life stages of fish has been tested rigorously with actual cylindrical screens in laboratory flumes at the Alden Research Laboratory in Massachusetts for Entergy's Indian Point Energy Center (IPEC; NAI and ASA 2011a and b). Alden is one of the premier hydraulic research institutions in the country. The objective was to quantify entrainment of fish eggs and larvae through cylindrical wedgewire screens that might be used in the Hudson River at the IPEC. Scale models of cylindrical screens with different slot sizes (2-9 mm; 0.08-0.35 in) and different through-screen velocities (0.25 and 0.5 f/s; 7.6 and 15.2 cm/s) were placed in water flowing at different velocities (0.25-1 f/s; 7.6-3 cm/s). Early life stages of several species (0.3-23 mm; 0.01-0.90 in long) were added to the water upstream of the screen and collected after entrainment through the screen and with nets at different locations around the screen. The trials were videotaped, fluid dynamics of the system was modeled, and the Computational Fluid Dynamics (CFD) models were used to plot trajectories of water, inanimate beads (simulating fish eggs), killed organisms (appropriate shape and mass but unable to express behavior), and live organisms (capable of behavior) as they either passed the screen or entered it. Data collected from entrainment and in the several nets were used to develop statistical models (combined for all species) of the fates of test organisms.

Four mechanisms were identified as contributing to the percentage of injected eggs or larvae that were entrained:

• *Hydraulic bypass* dominated in most situations. This mechanism was the physical ejection of the particle away from the nose cone of the screen by the bow wave. Inertia acting on the particles tended to move them away from the screen openings, even though water trajectories entered the screen's slots. Larger larvae/juveniles exhibited greater deflection from the screen, even in the absence of behavior.

• *Behavioral avoidance* of the fluid flows by the fish larvae (not seen for eggs) was apparent in most test runs. The larvae were able to sense the fluid flows at the nose cone and actively swim away from the screen sufficiently to generally avoid entrainment. Avoidance reactions continued when larvae were drawn close to the screen's slots. As with hydraulic bypass, larger larvae showed the most behavioral avoidance (fish larvae longer than 20 mm or 0.79 in showed a 90% probability of avoiding entrainment, likely due to increased swimming ability of larger larvae). A common perception that larvae cannot actively swim is incorrect.

• *Exclusion* by the slot size and through-screen velocity (varied through the tests), which have been the traditional measures of entrainment risk, was a relatively minor contributor to minimizing risk of entrainment.

• *Sweep off* involved eggs and larvae initially impinged on the screen that were progressively moved along the screen and eventually washed off. This, too, was a minor factor.

Establishing the dominant role of hydraulics at the "bow" of the cylindrical screen in entrainment avoidance was the major breakthrough result of the detailed flume study at Alden. That fish as young and small as larvae then exhibit behavioral (or physical momentum) responses to the velocity discontinuities of the "bow wave" to foster avoidance of entrainment was a further revelation.

Performance of a surrogate screen was also tested in the Hudson River (2-mm slot width, 0.25 f/s through-screen velocity; ASA and NAI 2012) to validate the laboratory flume results. Although detailed particle tracking was not possible under the field conditions, the concentration of organisms entrained through the screen was significantly less than the concentration measured in the river water. The test validated the Alden flume studies (NAI and ASA 2011a, b) and provided even better entrainment prevention than indicated in the laboratory. An unexpected result was that the capacity for behavioral avoidance, even by larvae, was shown when larvae actively avoided an unscreened control port that was initially intended to serve as the reference intake; ambient concentrations were then determined by Tucker trawl. Entrainment reductions by the test screen (entrained larvae versus ambient concentrations) were approximately 77%.

Results of the laboratory flume and field studies were determined to have general value for similar cylindrical screens. The observed mechanisms were incorporated in a general model of entrainment through cylindrical wedgewire screens (NAI and ASA 2011a). Data from pre-existing monitoring programs at power stations with operational cylindrical screens in similar estuarine locations were reviewed and compared to the Alden flume results using the general model (Barnthouse et al. 2011). The general model for entrainment reduction was validated by entrainment results at the other facilities. One of the facilities (Eddystone Generating Station) had screen openings of ¼ in (6.4 mm), close to the 3/8-in (10 mm) opening size at the Columbia Generating Station. A separate report corroborated in more detail the entrainment data from this station with the laboratory studies (AKRF and NAI 2011). AKRF (2011) also found that predicted entrainment reductions based on the results from the 2010 Alden flume study closely matched estimated entrainment reductions at the United Water New York in-river studies of 2009 and 2010.

Application to Downstream-migrating Salmon

There is concern by the NMFS that downstream migrating juveniles of species listed under the Endangered Species Act (Upper Columbia River spring Chinook salmon *Oncorhynchus tshawytscha* and Upper Columbia River steelhead *O. mykiss*), fall Chinook salmon and steelhead parr from spawning in the Hanford Reach, and coho salmon *O. kisutch* currently being reintroduced would be impinged and entrained at the cylindrical intake screen for cooling-tower makeup water for the Columbia Generating Station near Richland, Washington. This concern is prompted largely by an assumption that fish could be entrained in the 3/8-in (10 mm) openings of the perforated plate screen since the present screen does not conform to the NMFS' Facility Design Criteria for other types of screens (NMFS 2011, chapter 11). NMFS has pressed for replacement of the CGS screens with screens that meet the current NMFS design criteria.

The assumption that physical exclusion from the intake by pore size and through-screen velocity (the NMFS criteria) is the critical mechanism for entrainment protection is questionable based on the detailed study of entrainment of fish larvae discussed above. Hydraulic bypass and behavioral avoidance were the major factors for entrainment prevention for larvae at the test cylindrical screen, with entrainment prevention by these factors increasing with larval fish size. The same or greater protection by bypass and avoidance mechanisms would be expected for juvenile salmon. Juvenile salmon migrating or foraging in the mid-Columbia River are larger than the larvae studied above: emergent Chinook salmon and steelhead fry are about 25 mm (1 in) long (just above the largest 23 mm larvae studied for IPEC), "button-up" steelhead fry and Chinook salmon that could be rearing in the vicinity of CGS are about 35 mm (1.4 in) long, Chinook salmon zero age foragers are about 50 mm (2 in), Chinook sub-yearling migrants are about 75 mm (3 in), Chinook yearling migrants are about 100 mm (4 in), wild steelhead pre-smolt are about 125 mm (5 in), and hatchery steelhead about are about 150 mm (6 in) (Bell 1990 as cited by Norlund July 31, 2013).

The swimming behavior of migrating juvenile salmon and their capabilities for obstacle detection further support the view that hydraulic bypass and behavioral avoidance will predominate for these taxa. It has been recognized for some time that juvenile salmon usually migrate downstream in a head-upstream orientation while swimming slowly against the current (Coutant and Whitney 2000). It is generally understood that this behavior minimizes energy requirements for downstream migration while providing stability control and the ability to respond quickly to environmental stimuli. The mechanisms behind this behavior, founded in fluid dynamics of moving water, have recently been explored in detail in controlled laboratory settings. Naturally blind cave fish and experimentally blinded fish of other species have provided insights into the operation of the lateral line sensory system for detecting fluid flows and potential obstacles.

All fish have a lateral line system for detecting water flow in their surroundings (Bleckmann 2007). It is a system of water-filled tubes containing cells that detect water movement within the tubes. The system is most prominent along each side of a fish (thus, the "lateral line") but it also occurs abundantly in the head. The system is well developed in adult and juvenile salmonids, and is often the location for formation of air bubbles in gas-supersaturated water in Columbia River basin salmon (Coutant and Genoway 1968; Dawley and Ebel 1975). The lateral line system for detecting water currents develops early in the development of fish, beginning as surface neuromasts (sensory cells) in very early larvae and progressing to formation of the sensory tube system about the time of hatching (Blaxter 1986). It is well developed by the time salmonid alevins emerge from spawning gravels.

A fish uses its lateral line system to identify nearby objects and create a "picture" of the surroundings, an ability termed *hydrodynamic imaging* (Hassan 1989) without using vision. A swimming fish generates a flow field around itself due to the displacement of water at the head and suction in the tail region (Hassan 1989; Teyke 1988; Windsor et al. 2010; **Figure 3**). Pressure and water velocity stimulate the sensory cells in the various tubes of the lateral line system providing a "base case" of the fish moving in the open, ambient water (**Figure 3a**). When the fish moves into the proximity of an obstacle, its flow field will be distorted in a characteristic way that depends on the geometry and dimensions of the obstacle (**Figure 3b**). For a moving obstacle, or one in flowing water, the stimulus distribution in the fish's distorted lateral line system depends not only on the object location but the interaction of the fish's flow field with the flow field around the object (Hassan 1993). The spatial distributions of the stimuli to the lateral line system of a fish moving relative to objects has been derived mathematically as well as conceptually (Hassan 1992, 1993). The system also detects nearby changes in water velocity and direction characteristic of turbulent eddies, which are ubiquitous features of a flowing river environment, and likely aid migration or positioning in turbulent flows (Liao 2006).

When the fish stops moving in its surrounding water, its flow field collapses and the fish cannot orient itself with its lateral line system (Teyke 1985). Therefore, a downstream-migrating salmon fry or smolt must swim, rather than drift passively, in order to maintain its ability to detect objects or otherwise direct its movement relative to its physical surroundings such as turbulent eddies. This explains why a downstream-migrating fish would either swim gently facing upstream (as usually seen) or swim rapidly downstream (as seen occasionally). Head-upstream orientation provides opportunity for a longer warning time when encountering an obstacle than when racing downstream, perhaps explaining the preponderance of the head-upstream orientation. It is also the most efficient for the fish energetically.

This basic scientific information is in accord with observations of downstream movements of juvenile steelhead at night as they approached an experimental flow deflector (Bevelhimer and Coutant 2008). The hatchery-produced steelhead (average length about 21 cm/8.3 in) were moving downstream with water flow into the intake canal of the Buchanan Hydroelectric Power Project on the St. Joseph River, Michigan. The fish were marked by attached chemoluminescent light tags visible at several meters depth and followed visually from an overhead platform. An occasional fish swam close enough to the surface that we could see the fish itself and confirm that it was swimming head upstream. The fish showed a clear ability to detect the deflector well upstream of it. Of the 61tagged fish that approached the deflector from upstream, 39 (64%) went around it by passing to the side or under it. The remainder slowed their movement and often held position immediately in front of the deflector's baffles before moving through slots in the array. The fish appeared to have altered their trajectory when they reached the beginning of the bow wave, which was located by observations of the velocity of drifting surface debris in daylight. The relevance of this study is not the deflector itself but the significant ability of the steelhead to detect and avoid the deflector's baffles well in advance of actually encountering the physical baffles.

Salmon Fry and Smolts – Columbia River

The cylindrical intake screens for cooling tower make-up water for the Columbia Generating Station in the Columbia River near Richland, Washington **(Figures 4 through 7)** have been shown to impinge or entrain no juvenile salmonids (WPPSS 1985). This was determined in a monitoring program for entrainment and impingement during plant operation in April-September 1985. This result was in spite of nearby spawning sites for fall Chinook salmon and steelhead, and the reach being a migration corridor for out-migrating smolts of several salmonid species from upriver locations including some species listed under the Endangered Species Act (NRC 2011). The monitoring program confirmed that juvenile salmonids were present in the river reach containing the intake during the monitoring. There were both migrants from upriver and foraging Chinook salmon parr. In principle, salmonid fry and smolts as large as 80 mm (3.1 in) would be able to pass into the 9.5 mm (3/8 in) diameter holes of the CGS intake screens depending on the body height of the fish (Bell 1990; Norlund July 31, 2013). This might occur with approach velocities of 0.05 m/s (0.15 f/s) under normal 2-screen operation (0.2 to 0.34 m/s or 0.50 to 1.1 f/s under rare single-screen operation) (WPPSS 1985). Why there has been no observed entrainment and impingement over 28 years of operation is, therefore, a legitimate question.

A likely protective scenario can be envisioned for salmon fry and smolts encountering a cylindrical screen in the Columbia River based on the scientific literature on hydrodynamic imaging by fish, the Alden/IPEC flume studies that identified hydraulic bypass of fish larvae, and personal observations of steelhead smolt behavior while approaching an obstacle. The scenario would be as follows:

- A salmon or steelhead fry or smolt initially occupies the mildly turbulent ambient flow of the river, swimming gently with its head upstream. This would be the case for a migrating yearling, a migrating underyearling or a parr that is temporarily in the river channel as it moves around in its mostly shoreline foraging. Its gentle swimming against the current generates a flow field around its body that is registered by its lateral line system and transmitted to its brain, which recognizes the steady-state condition. That register is not static, but fluctuates within the bounds of change caused by the normally turbulent river flow.
- As it drifts downstream toward the cylindrical screen, the fish encounters a sharp decrease in velocity caused by the initial null point of the screen's bow wave. This velocity change alters its own flow field and signals a fluctuation that is more than normal. The fish is alerted to take evasive action.
- The fish may initiate more active swimming behavior, usually in the form of a short burst of swimming, to avoid the sharp decrease in velocity, causing the fish to move around the cylinder with the bow wave.
- If the fish is moving in a trajectory aligned with the center line of the screen, and does not swim away from the sharp velocity gradient, it may enter a zone of zero or low velocity, where it might linger (not likely at the CGS screens because the nose cone is

quite pointed, thus minimizing a zone of low to zero velocity seen at more blunt obstacles).

• If the fish is on a trajectory to a side, top or bottom of the cylinder, it encounters the lateral velocity changes associated with the bow wave. Its flow field is least disturbed when it moves along the bow wave and away from the cylinder, so the fish makes fine-scaled movements to follow that trajectory.

• The physical spreading of the flow around the cylinder in the form of the bow wave moves the fish around the cylinder. Inertia on the fish mass and avoidance swimming or orientation behavior counteract the pull of water into the screen's orifices thus minimizing entrainment and impingement.

• While the fish is responding physically and behaviorally to the velocity changes associated with the bow wave, water is entering the screen through its own independent trajectory (flow net) as shown in model studies (Alam et al. 1974; NAI and ASA 2011a).

• Any fish at risk of being impinged on the screen by in-flowing water is rapidly washed off by the river's strong sweeping velocity along the screen.

• Some fish may find the low-velocity zones downstream of the cylinder and its supporting pipe attractive refuges and may linger there temporarily (similar to responses to natural obstacles such as large rocks).

General Conclusions

We are now beginning to understand why cylindrical intake screens oriented parallel with the current in flowing water have low to non-existent entrainment and impingement of fish. Recent and detailed laboratory flume studies of fish eggs and larvae at cylindrical screens, basic scientific research on fluid dynamics of fish perception, and field studies of fish encountering obstacles have provided important evidence. The fluid dynamics of a cylindrical screen in flowing water coupled with a fish's size-dependent ability to sense changes in the fluid dynamics of its surroundings (empowered by its own swimming motions) combine to nearly ensure that there will be little vulnerability of migrating fish larger than about 20 mm (0.8 in) to a porous cylindrical screen. Cylindrical screens oriented parallel with the current in flowing water have unique hydraulics that create important opportunities for fish avoidance not appropriately addressed by existing NMFS screen criteria, which were developed for different screen types. Reassessment of the assumptions behind screen design criteria seems warranted when applied to cylindrical screens in flowing water.

Consideration of Specific NMFS Objections to the CGS intake

NMFS has raised specific objections to the relicensing (NRC) and NPDES permit renewal (Washington's Energy Facility Site Evaluation Council and Department of Ecology, EFSEC/WDOE) for the make-up water intake for the steam generator cooling system. These objections were put forward in letters from NMFS to the U.S. Nuclear Regulatory Commission (NRC; NMFS October 24, 2011) and the U.S. Environmental Protection Agency Region 10 (EPA; NMFS August 6, 2013). Technical assessments are contained in two attachments to NMFS's August 6, 2013 letter (Norlund. July 31, 2013 and August 7, 2013). NMFS also was critical of certain statements in the original version of this discussion paper (NMFS December 12, 2013). This section addresses the technical information and opinions in the August correspondence in the context of the scientific information presented above. Responses to NMFS December 12, 2013 comments on the initial discussion paper are provided separately (Coutant 2014).

NMFS (NMFS October 24, 2011) contends that: *Due to the cooling water intake being located downstream of known spawning areas and within the migration corridor of ESA-listed salmon and steelhead, there is a potential for entrainment of juvenile salmonids under the proposed action. As the intake screening system is not consistent with NMFS's screen criteria* [NMFS 2011] *and given the frequency of its operation, we cannot say that adverse effects from entrainment are extremely unlikely to occur, therefore this potential is not discountable. … NRC should develop a cooling water intake system design that meets NMFS's criteria, and a schedule for implementation, as an addition to the proposed action identified in your BA* [Biological Assessment; NRC 2011]. This concern was carried to the EPA for EPA's consideration in reviewing the preliminary conclusions by Washington's Energy Facility Site Evaluation Council and Department of Ecology. Those agencies concluded that the proposed NPDES permit for the existing facility design would have only minor detrimental effect on Federally listed species (NMFS August 6, 2013). Expanding on its October 24, 2011 letter to the NRC, NMFS's letter to EPA states that: *As proposed, this permit would harm these anadromous salmonids, resulting in prohibited take under the ESA. Furthermore, it would allow reduction of the conservation value of essential fish habitat for Chinook salmon, contrary to the requirements of the Magnuson Act.*

It is important to clarify that NMFS does not have screen design criteria specifically for cylindrical screens oriented parallel with the current in flowing water, which is the screen type in place at the CGS since the early 1980s. Chapter 11 of NMFS 2011, which is cited by NMFS as the basis for its concern for not meeting criteria, provides hydraulic criteria for rotating drum screens, vertical screens and inclined screens (Section 11.6, page 89-93) and screen material (Section 11.7, page 93-94). Criteria listed for these types of screens are the ones that the NMFS asserts are not met by the CGS intake.

The presence of known spawning and migration areas near the cooling-water intake does present the *potential* for entrainment of juvenile salmonids. As the above presentation describes, however, the functional design for minimizing risk of fish entrainment by a cylindrical screen in flowing water is different than for the screen types covered by NMFS 2011. Further, the introduction to Chapter 11 states: "Unless directly specified herein, this guidance is not intended for use in evaluation of existing facilities."

Using information provided by NMFS in its correspondence (Bell 1990) it is evident that the ESA-listed species are at very low risk from entrainment at the CGS intakes. This is due to their large size at time of migration through the river near the CGS. The NMFS contentions thus revolve around the locally produced Hanford fall Chinook salmon and steelhead parr, further emphasized in NMFS's December 12, 2013 letter to Energy Northwest.

The following sections respond to points made by Mr. Brian Nordlund in the two technical attachments to NMFS August 6, 2013 letter to EPA, following the outlines and section headings of each attachment.

Nordlund July 31, 2013

Screen Design Expertise. We respect Mr. Nordlund's experience with fish passage structures and his active participation in numerous working groups related to fish screening. Design criteria promulgated by NMFS have saved many thousands of salmonids, particularly at irrigation-water withdrawals. We respectfully suggest, however, that his experience as a fish passage engineer may not necessarily imply that he is abreast of relevant fish sensory capabilities and behavior, particularly in relation to the hydraulics of cylindrical screens oriented parallel to the current in flowing water. We encourage Mr. Nordlund to pursue the references cited in the brief review above and engage NMFS's biologists before finalizing his best professional judgment regarding the CGS intake.

Site Specific Screen Entrainment Study Requirements. We disagree with Mr. Nordlund that a "physical entrainment study" (site specific screen entrainment study) must be expensive and would "rarely result in demonstrable evidence that fish are not impinged or entrained." With the hydraulic and biological framework discussed above, a focused study to confirm low (or no) impingement or entrainment could be conducted if warranted. In fact, such a study was conducted in 1985 for the CGS, with no fish captured (WPPSS 1985). Although the factors described are pertinent to impingement and entrainment generally (species, sizes, timing, river flows, temperatures, time of day, etc.), it is not necessary to provide 100% empirical results for all of these factors when a solid knowledge base is available for a focused assessment. This is particularly true when the physical and biological factors that have been demonstrated for a cylindrical screen such as deployed at the CGS indicate that impingement and entrainment would be low to rare.

Screen Entrainment. Milo Bell's handbook (Bell 1990) has been a very useful compendium of data and analysis techniques, but neither he nor the other studies that were cited evaluated the hydraulics of a cylindrical screen oriented parallel to the current in flowing water or the sensory and behavioral capabilities of fish approaching such a screen from upstream. The dimensions of a fish's body relative to the size of the screen perforation have little relevance when the fish is physically deflected by the bow wave of the cylinder (hydraulic bypass) and behaviorally responds to the changes in water velocity by moving away, as discussed above. Despite the size of Table 1, the only real conflict it indicates with the CGS intake is for Chinook zero-age and subyearlings. Emergent and "button-up" steelhead and Chinook fry are acknowledged to be unlikely at the CGS site (they are in-gravel stages), while larger Chinook subyearlings, wild steelhead pre-smolt and hatchery steelhead smolts are acknowledged to be too large to be entrained by a 3/8-inch pore size. The hydraulics of a cylindrical screen would certainly deflect 50-75-mm-long Chinook salmon because the Alden flume studies indicated that hydraulic bypass was 90% effective for fish larvae 20 mm long (NAI and ASA 2011a). In addition, zero-age Chinook salmon have a well developed and functional lateral line system that indicates capability for behavioral avoidance (they also move downstream with a head-upstream orientation, indicating a functional obstacle-avoidance strategy).

The length-frequency data presented from the "Dauble Report" (Dauble et al. 1989) are instructive in supporting the conclusion that the 0-age Chinook are large enough to be deflected by the hydraulics of a cylindrical screen. As noted above, the Alden flume studies showed a 90% hydraulic bypass of fish larvae 20 mm long. Deflection was progressively greater at ever-larger sizes. All Chinook reported in the figure from Dauble et al. (1989) were 35 mm or larger (most >40 mm) at which size they are active swimmers as noted by Mr. Nordlund in his last paragraph. When Chinook of this size encounter the screen, either through foraging or being swept downstream, they would be subject to the cylinder's hydraulics and its influence on their avoidance behavior.

NMFS Screen Criteria. None of the studies cited by Mr. Nordlund in support of a 3/32-inch pore size criterion included cylindrical screens in a river placement similar to that at the CGS. The habitat descriptions for salmonids in the vicinity of the CGS intake are correct, and thus these fish are potentially susceptible to being entrained. The detailed hydraulics of cylindrical screens and the sensory capabilities of young salmonids, however, combine to make entrainment unlikely (as confirmed by actual monitoring of entrainment at CGS in 1985).

Nordlund August 7, 2013

As commented on his July 31, 2013 Memorandum for Hydro Division Files, we respect Mr. Nordlund's experience with salmonids but question whether this experience is fully relevant to evaluating the specific hydraulics and biological responses associated with a cylindrical screen in flowing water, which is the type used for the CGS station intake. That he has evaluated fish screens ranging in capacity from a fraction of a cubic foot per second (cfs) to 6,000 cfs, as he states, is not directly pertinent when these screens are not of the form, orientation and hydraulics being evaluated for the CGS. Mr. Nordlund states that he is giving his "professional opinion" concerning the CGS intake system. The EPA has consistently relied on "Best Professional Judgment" on a case-by-case basis for evaluating existing facilities not subject to categorical section 316(b) regulations (EPA August 8, 2013). It is important, therefore, to ensure that Mr. Nordlund's professional opinion and other relevant scientific opinions are considered to arrive at the "Best Professional Judgment" in the CGS case.

Fish Presence. Mr. Nordlund acknowledges that the CGS screens were designed to minimize the impact of water withdrawal on salmonid fry, yet he seeks further improvement. Information on hydraulics and behavioral responses now available for cylindrical screens parallel to the current in flowing water (see discussion above) indicate that impingement and entrainment should be low to rare with the existing intake system. Physical modeling of the proposed CGS screens was specifically directed at protecting fish in the vicinity (Alam et al. 1974). A monitoring study demonstrated that no salmonids were entrained in 1985 while the facility was operating and fish of concern to NMFS were present in the river. In spite of the CGS intake not meeting certain NMFS criteria (developed for very different screen designs), the CGS intake has a demonstrated zero observed impingement and entrainment. It is not clear what level of further improvement could be made.

Screen Design. Mr. Nordlund is correct that the CGS intake does not meet certain screen design standards as expressed in NMFS's *Anadromous Salmonid Passage Facility Design* manual (2011). There are facility and site-specific considerations, however, that warrant attention for application of Best Professional Judgment, as discussed below.

Screen Cleaner. The NMFS definitions of active and passive screens (NMFS 2011) are not appropriate for cylindrical screens in flowing water. A cylindrical screen in flowing water is situated so that ambient flow surrounding the cylinder washes away debris. There is rarely a need for a screen cleaner, especially in water that is generally as clean as the Columbia River. This is substantiated by nearly 30 years of operation of the CGS screens without screen cleaners and without debris problems. Despite the NMFS definitions, a cylindrical screen of whatever diversion rate is a passive screen with respect to debris cleaning. The NMFS criterion requiring a screen cleaner is not met because it is not needed.

Screen Submergence. The NMFS criterion for screen submergence at the minimum water elevation also does not consider the unique hydraulics of cylindrical screens. A bow wave in front of the cylinder is as effective, or more so, at deflecting fish and other material in shallow water as would be the case in deeper water. An increase in velocity at the top of a screen in shallow water described by Mr. Nordlund (compared to deeper water) would be more likely to both physically deflect fish and stimulate behavioral avoidance. A fish would not be swimming against the higher velocity as suggested, but would move laterally along the velocity gradient. There would be a higher sweeping flow that would decrease the likelihood that a fish could be captured by the water flow net into the screen. At a high sweeping flow, there would be no lingering at the screen for fatigue or to be eaten. Furthermore, minimum flows in the Columbia River do not coincide with the occurrence of the vulnerable life stages of salmonids of concern to NMFS, as noted by Mr. Nordlund in his conclusion. Most salmon outmigration occurs during the spring period of high flows.

Screen Face Material. A requirement that the perforated-plate screen face openings be no larger than 3/32-inch in diameter also does not consider the hydraulics of a cylindrical screen oriented parallel to the current in flowing water. As demonstrated even for fish larvae, the hydraulics of water passing a cylinder and the behavioral responses of fish to changes in velocity as they approach an obstacle minimize the presence of the fish near the screen openings. This was shown even for larval fish, which are weak swimmers, especially when larvae were 20 mm or larger (NAI and ASA 2011a). As noted above, the salmonids of concern for the CGS are larger than 20 mm, proficient swimmers, and with a swimming orientation that fosters recognition of an obstacle and effective avoidance.

Bell's work was largely related to screens in which water approaches perpendicular to the screen, or nearly so, and without the hydraulic bow wave or fishes' behavioral reactions to bow-wave changes in water velocity. Mr. Nordlund asserts that "A 3/8th inch perforated plate screen has never been tested for salmonid entrainment ... because it intuitively makes sense that any diameter hole larger than 3/32th inch would entrain small juvenile salmon." The CGS monitoring study in 1985 did, however, test the existing screen system during the presence of the salmon of concern and found no entrainment whatsoever (WPPSS 1985).

The concern for impingement by a 3/8th inch pore size in the CGS cylindrical screen is likewise unsupported by scientific evidence. For reasons explained above, fish would be diverted away from the screen face by the hydraulics of a cylinder in flowing water and the behavioral reaction to velocity changes as a fish approaches the cylinder. There also would be a rapid sweeping flow along the screen face for any fish that did approach the screen openings ("sweep off" in the Alden/Indian Point study). Model studies for the CGS screens showed that the acceleration into an orifice starts at a distance of about one to two diameters from the orifice (Alam et al. 1974), which means that nearly all fish would be beyond that distance (~3/4 in) as they pass the screen.

<u>Screen Approach Velocity</u>. Mr. Nordlund acknowledges that the NMFS criterion for approach velocity is met. Nonetheless, the concept of approach velocity needs to be reconsidered in the context of high sweeping velocities along a cylindrical screen. The velocity vector parallel with the screen face would far surpass the vector leading to the screen opening. The CGS screen-modeling studies found that at a distance of ¾ in from the surface the longitudinal velocity was predominant (Alam et al. 1974).

<u>Conclusion</u> (Nordlund's). Mr. Nordlund makes four recommendations for improvement of the CGS screens, for which we summarize our opinion based on the discussion above:

1. *Design and installation of a waterjet back spray cleaning system.* This is not necessary based on nearly 30 years of CGS operation and without scientific justification. The hydraulics of a cylindrical screen located in water flowing at rates found at the site nearly preclude clogging of the screen by debris. This was demonstrated in the Indian Point field study in the Hudson River where the anticipated clogging of the screen by high debris loads did not occur. A strong bow wave and high sweeping flows along the screen face combine to prevent debris from attaching to the screen.
2. *Replacement of screen mesh with 3/32" stainless steel perforated plate.* This is not necessary and without scientific justification based on the literature summarized above. Entrainment of downstream-moving juvenile salmonids into either the existing or recommended pore size is nearly precluded by the hydraulics of a cylindrical screen in rapidly flowing water and the sensory capabilities and avoidance responses of the fish.
3. *Balance of screen approach velocities by installing an internal baffle with porosity varied to distribute flow evenly over the entire screen surface.* The present system already contains an internal perforated pipe to serve the recommended function, as a result of model studies (Alam et al. 1974). This is

actually less necessary considering the low importance of approach velocity to entrainment in a cylindrical screen in rapidly flowing water.

4. *Install the screens at a lower elevation, if feasible.* This is not biologically necessary, considering the hydraulics of a cylindrical screen, the likely avoidance responses by moving fish, and considering that minimum water elevations generally occur when the fish of concern are not present (downstream migrants move during seasonal high water).

Energy Northwest's Conclusions

• Considerable scientific evidence indicates that Non-Concurrence by NMFS with the NRC's Biological Assessment and Essential Fish Habitat Assessment for ESA listed species (NRC 2011) is not justified. The NRC report is a comprehensive and valid evaluation of the risks to the listed Columbia River's salmonids by the CGS's intake, with conclusions of "no effect" (bull trout) or "may affect, but not likely to adversely affect" (Upper Columbia River Spring Chinook salmon, Upper Columbia River steelhead). The CGS intake is concluded to have "a minimal adverse effect" on Upper Columbia River Chinook salmon and coho salmon. These conclusions are scientifically justified based on information in the NRC report and supported by additional information on the hydraulics of cylindrical screens and the sensory and behavioral avoidance capabilities of the fish discussed above.

• NMFS's screen design criteria, on which the non-concurrence is based, do not reflect the unique hydraulics of cylindrical screens oriented parallel with the current in flowing water such as the CGS intake, due to their being based on experiences with other types of screen systems having quite different orientations and fluid flows. The unique hydraulics of cylindrical screens includes strong bow waves at the leading cone and high sweeping flows along the screen faces.

• Experimental flume studies with fish larvae at Alden Laboratories for the Indian Point Energy Center have provided understanding of the hydraulic and biological responses associated with cylindrical screens in flowing water relevant to the CGS intake. These studies indicated that hydraulic bypass was the dominant mechanism that minimized entrainment, aided by behavioral avoidance especially by larger larvae, while passage through the screen pores was a minor component of avoiding entrainment. With these results for small and weakly swimming fish larvae it is difficult to believe that larger, more strongly swimming juvenile salmon would avoid entrainment any less.

• Potential vulnerability to entrainment of salmonids found near the CGS would vary by fish size, as indicated by NMFS based on compilations by Bell (1990). Smallest sizes would not be vulnerable due to residence in gravels. Largest sizes typical of yearling migrants of upstream ESA-listed stocks would be too large to be entrained by CGS's pore size. The mid-range of potentially vulnerable sizes (parr) is above the larval size that the Alden flume studies indicated had >90% entrainment avoidance. Thus, overall vulnerability of juvenile salmon is low.

• NMFS's screen design criteria do not reflect the sensory capabilities of downstream-moving juvenile salmonids to detect and respond to the unique hydraulics of cylindrical screens oriented parallel to the current in flowing water.

• Application of Best Professional Judgment to the CGS intake should take into consideration the hydraulic literature regarding cylindrical screens and the relevant biological literature on fish sensory capabilities and behavioral responses, especially for the salmonids of concern to NMFS.

• Scientific evidence, including actual on-site monitoring of entrainment at the CGS, strongly supports the conclusion that the CGS intake system of cylindrical screens in a Columbia River reach of flowing water is adequately protective of the ESA-listed salmonid species and the locally spawning Hanford Chinook salmon and steelhead. No "take" has been shown and none would be expected on the basis of current scientific understanding of the intake system and relevant fish responses.

• Modification of the CGS intake along the lines recommended by NMFS are not scientifically justified and would bring small, if any, benefits to salmon.

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Figure Legends

Figure 1. An example of a cylindrical screen placed in a river parallel with the current flow. Water velocity magnitudes (f/s) are shown surrounding the cylinder for a low withdrawal rate (Upper) and a medium withdrawal rate (Lower), based on CFD modeling. Ambient flow is from right to left. Water enters the dark blue areas of screening and passes through the vertical pipe to a pumping station. From NAI and ASA 2011a, Appendix D.

Figure 2. Summary schematic showing the anatomy of the flow around a D-cylinder and the positions of fish. A trout swimming in (a) uniform flow, (b) in the bow wake, (c) entraining in the suction region behind the obstacle, and (d) in the Kármán vortex street downstream. From Liao 2007, Figure 6.

Figure 3. Schematic diagram of the flow field around a gliding fish. Left: in open water. Right: passing an obstacle. From Hassan 1989, Figure 10.1.

Figure 4. Spare perforated-plate cylindrical intake screen (side view) for the Columbia Generating Station. This unit is one half of the completely assembled cylindrical screen and would be upstream or downstream of the vertical pipe leading to the pump house (see Figure 6).

Figure 5. Diagram of the cooling-water intake system of the Columbia Generating Station from the in-river intake screens (right) to the pump house (left), in plan view (top) and profile view (bottom). From WPPSS 1980 as used in NRC 2011.

Figure 6. The structure and placement of the Columbia Generating Station in-river screens, in plan (top), cross section (middle) and profile (bottom) views. Only the minimum low water elevation is shown (see Figure 5 for normal river elevation). From WPPSS 1980 as used in NRC 2011.

Figure 7. Artists rendering of the cooling-water intake system of the Columbia Generating Station from the in-river intake screens to the pump house.

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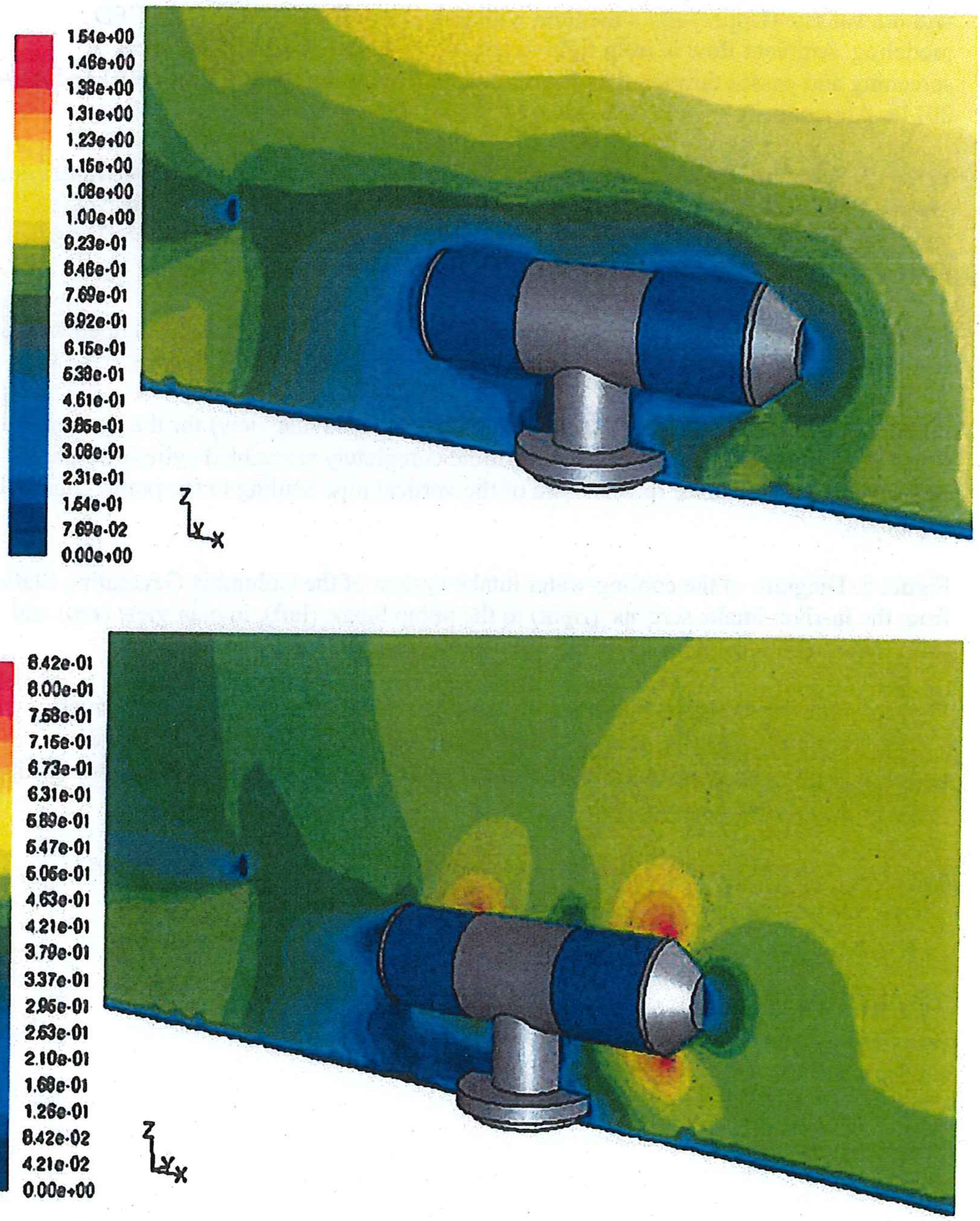

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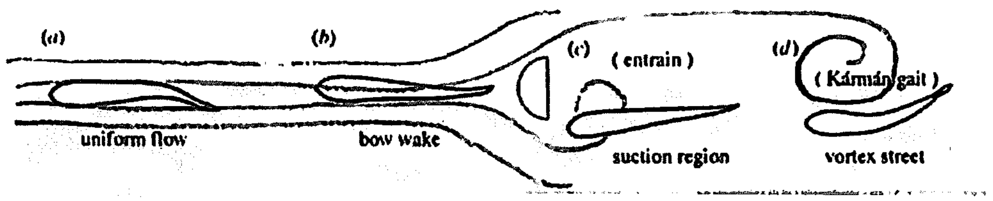

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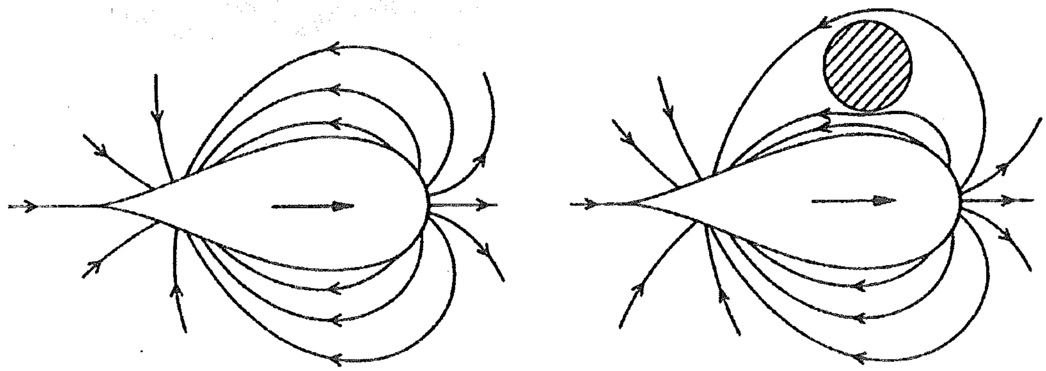

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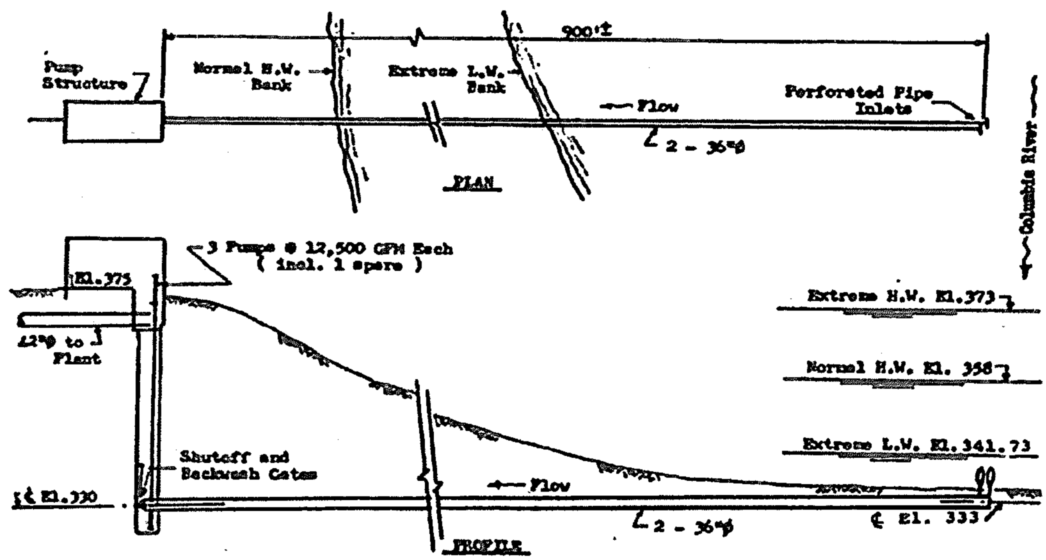

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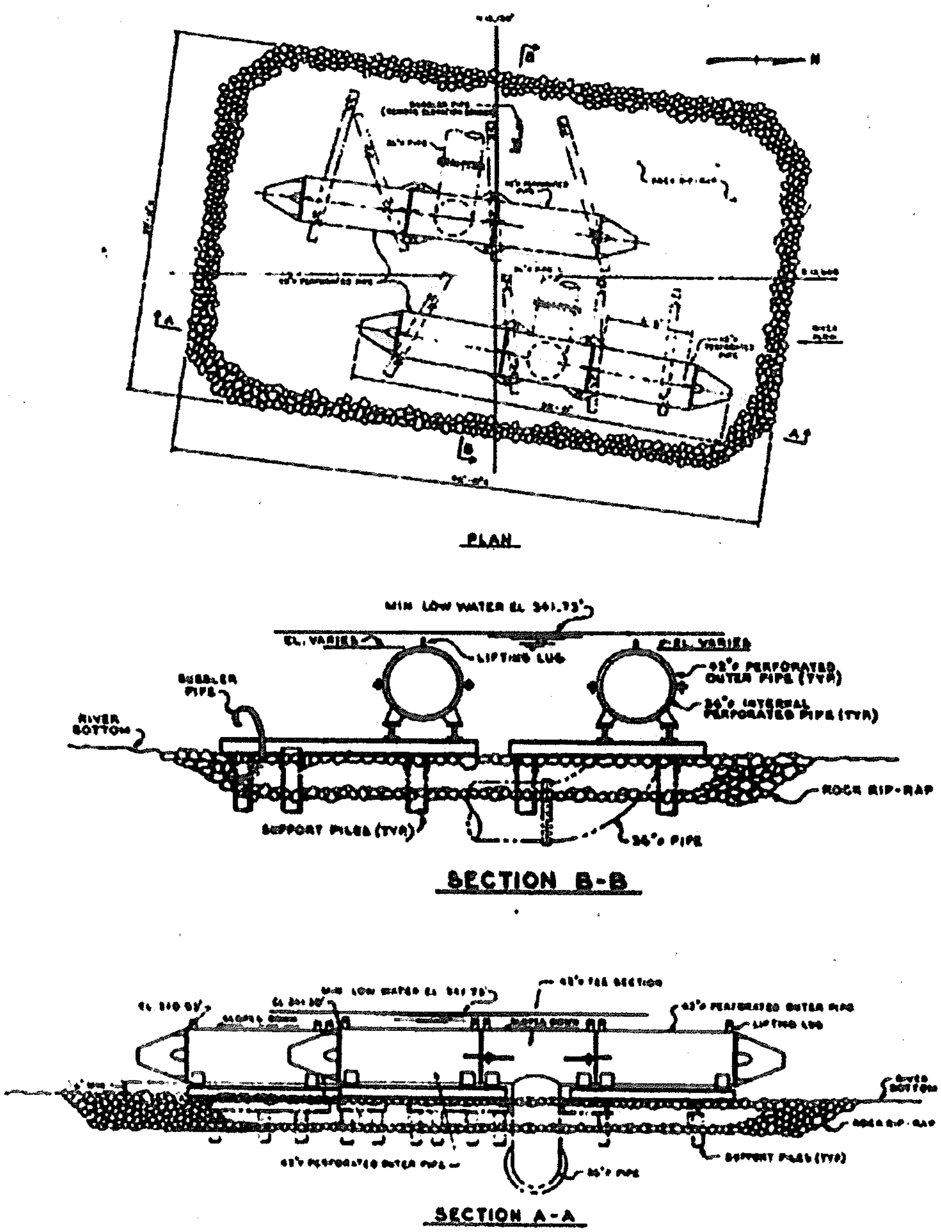

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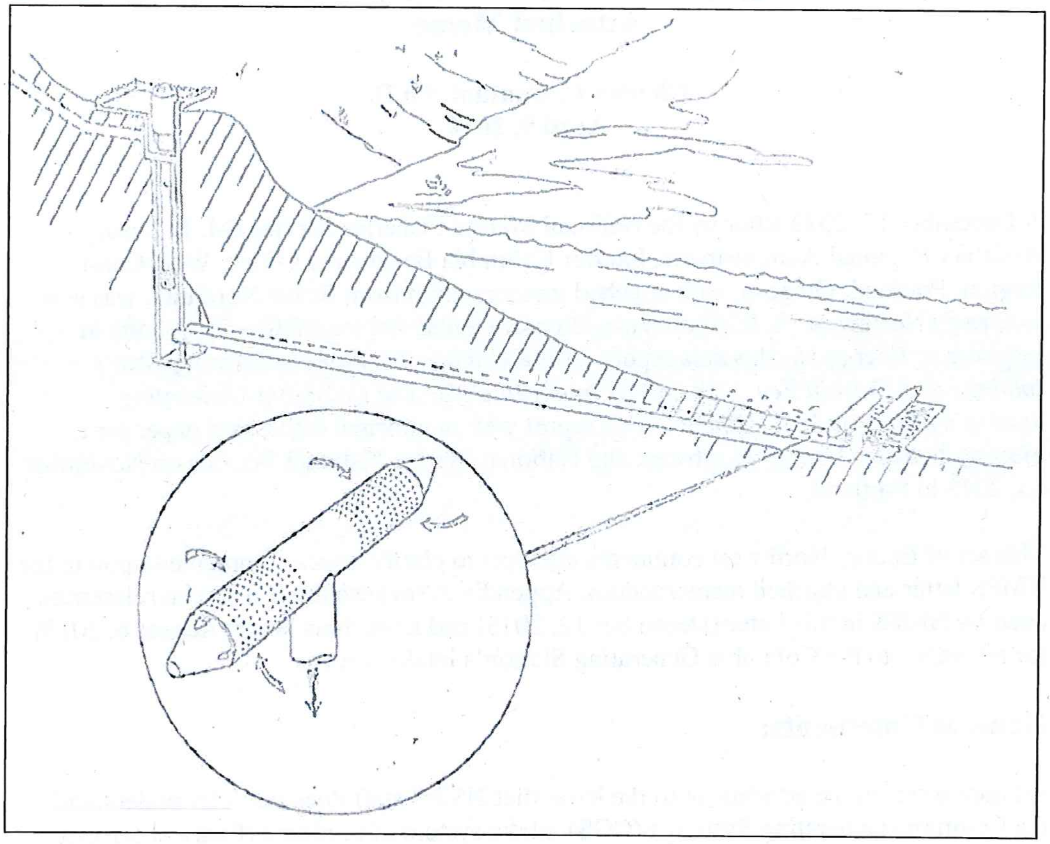

Comments on NMFS letter of December 12, 2013 to Shannon Khounnala of Energy Northwest by Michael P. Tehan of NMFS, with its Attached Memo

Charles C. Coutant, Ph.D.
April 9, 2014

A December 12, 2013 letter by the National Marine Fisheries Service (M. P. Tehan, Assistant Regional Administrator, Interior Columbia Basin Area Office, West Coast Region, Portland, Oregon), with attached memorandum from Bryan Nordlund, was sent to Energy Northwest (S. E. Khounnala, Environmental and Regulatory Programs) in response to Energy Northwest's report: *Why Cylindrical Screens in Flowing Water Impinge and Entrain Few Fish and Its Importance for The Columbia Generating Station's Intake* by C. C. Coutant. This report was an informal discussion paper for a meeting between Energy Northwest and National Marine Fisheries Service on November 13, 2013 in Portland.

This set of Energy Northwest comments attempts to clarify issues commented upon in the NMFS letter and attached memorandum. Appendix A reviews the fish screen references cited by NMFS in this letter (December 12, 2013) and a previous letter (August 6, 2013) for relevance to the Columbia Generating Station's intake screens.

General Comments:

• It appears from the attachment to the letter that NMFS staff does not fully understand the Columbia Generating System's (CGS) intake system of in-river cylindrical screens oriented in line with river flow despite our meeting on November 13, 2013. Many aspects of what were analyzed and presented by Energy Northwest (ENW) were misinterpreted by NMFS due to this apparent incomplete understanding.

• The NMFS comments suggest that the agency believes the CGS intake system is a proposed, new system whereas it has been operating successfully in the same place and with the generally expanding salmon populations for nearly 30 years. The hypothesized, detrimental impacts to juvenile salmon have not occurred.

• Detailed biological studies of entrainment in cylindrical screens in flowing water conducted by Alden Hydraulic Laboratories for the Indian Point Energy Center (provided to NMFS by Energy Northwest) do not seem to have been fully appreciated and used by NMFS staff in evaluating the CGS screening facility.

• Although the initial NMFS correspondence re the CGS intake was related to ESA consultation over entrainment of listed species, NMFS' latest comments relate to protection of fry of Hanford fall Chinook, which is not ESA listed and is a thriving population.

• NMFS seems to have not fully considered results of the 1980 pre-operational and 1985 operational entrainment studies that were conducted (with NMFS study-plan review) to assess many of the issues raised hypothetically in the NMFS letter and attachment.

• The main objective of the NMFS letter with attachment seems to be to defend and enforce application of their current (July 2011) screening criteria (e.g., pore size, approach velocity, debris removal) with little attempt to understand what the CGS intake system actually is and how it has performed.

• The NMFS fish-screen experience appears from the references they cite to be primarily with screening of water diversions in irrigation canals using angled rotary drum screens or bar screens, which are unlike the CGS's in-river, cylindrical screens used for cooling-tower make-up water (Appendix A).

Detailed Comments on the Attachment (headings and numbering are those of the attachment):

1985 Entrainment Report

As noted in the 1985 monitoring report, the 1985 entrainment study was conducted with NMFS oversight and with incorporation of NMFS's recommendations.

NMFS is apparently correct that no control releases of Chinook fry were made into the entrainment capture cages inside the intake well located at the pump house. Thus, the capture efficiency of the monitoring cages is undetermined. However, if entrainment through the in-river screens was occurring at detrimental levels now suggested by NMFS, some Chinook fry should have been detected in the collection cages or cooling-tower basin (if leaked around the collection cages).

It seems unlikely that all fry entrained by the intake would have passed through poor seals, poor joints between mesh panels, mesh distortions, gaps in closure gates or spillback of flow into the sump, as NMFS suggests. Water is checked daily in the cooling-tower basin by Energy Northwest Operations staff. Interviews with some operators who have been with the company since start-up in 1985 indicate that they have never seen (or heard from other operators) of juvenile fish or fish parts being observed in the basin. When records of the Corrective Action System (documentation of all current and historical records) were checked, there was no record of live fish or fish parts having been found.

There was no plunging flow into the capture cages, as NMFS suggests. Water in the intake well at the pump house is essentially at river water elevation. The entrances to the capture cages were submerged.

NMFS makes a valid point about a general need for rigor in monitoring. However, the likelihood of entrainment is vanishingly small with the CGS intake system based on existing monitoring studies, 28 years of operation without noticeable loss of young salmon in the system, and fundamental science of hydraulics and fish behavior (some obtained recently in flume tests with fish larvae). Thus, the need for an increasingly rigorous effort to detect any entrainment at the CGS intake seems unjustified.

2013 Coutant Memo

1) Although the Alden/Indian Point Energy Center study reports were provided to NMFS, the NMFS letter indicates some misunderstanding of them.

• The Indian Point studies were not at the Indian Point plant intake, but were with a rigorously tested screen in the Alden Research Laboratories' test flume in Holden, Massachusetts. Only one test was in the river, and it was a verification test following the flume tests and clearly labeled as the only "in-river test."

• Fish behavior was not the major factor found effective in those Alden/Indian Point studies; the NMFS critique in this paragraph emphasized fish behavior. The physical effects of flow dynamics alone around the cylinder ("hydraulic bypass") were the primary factors in minimizing entrainment of fish larvae in those controlled tests. Behavior of the larval fish to those physical effects was secondary, but still important especially for the larger sizes of larvae (>20 mm).

• It was not the intent of the ENW material to claim that behavioral response to a screen was unique to cylindrical screens. It is the particular hydraulics of flow around an in-river, cylindrical screen oriented parallel with river flow plus fish reactions to that flow that is unique among intake screens.

• Although the NMFS Design Manual contains reference to cylindrical screens, the end-of-pipe cylindrical screen that NMFS staff drew on the board at the November 13 meeting was oriented perpendicular to the river flow and was a perforated extension of the intake pipe. Reading of the NMFS Design Manual found no reference specific to a screen like CGS's that is oriented parallel with river flow. In a review of water intake screens, Nordlund (Nordlund, B. 2008. Designing fish screens for fish protection at water diversions. National Marine Fisheries Service, Lacy, Washington.) briefly introduces a design similar to that at the CGS as one type of Pump Intake Screens. He states that it is for use in a "pressurized system", which the CGS is not. He states that it is appropriate for "small pump intake screens" for "small irrigation diversions." It would be helpful if NMFS would point out where in the Design Manual this type of screen is discussed and the studies that were used as references for its discussion.

• The 90% figure in the Alden study was for fish larvae, whereas the point of discussing lateral line sensing and behavioral response was for salmon fry the size of those found at Hanford and larger (the ESA species that migrate past CGS at larger sizes than Hanford fry).

• If entrainment is already zero, which the earlier studies indicated, then adjusting the pore size to meet NMFS general criteria would not increase the chance of survival as the NMFS comment professes. If the entrainment is not zero but only very low, which might have been possible in the earlier monitoring studies, then the increase in survival using the NMFS criteria would be slight and cost effectiveness of changing the screens would be questionable.

2) The 3/8 " pore size was long the industry standard, and is still the predominant pore size at water intakes nationally. It was common when the CGS intake was designed. NMFS' current criteria for smaller pore sizes are clearly better for minimizing entrainment for most screen types but that does not take away from the fact of history and practice.

3) Comments about debris problems suggest that this is a proposed installation rather than a re-permitting of an intake that has been operating successfully for 28 years with no cleaning system and no debris problems. Operations personnel are aware of potential debris issues, and know to report any instances; there have been none reported.

The Coutant work on the Cowlitz River was misrepresented. The company, Natural Solutions (Gordon Burns), and USGS Columbia River Research Laboratory have tested enhanced-velocity fish guidance systems periodically on the Cowlitz for brief periods during smolt out-migrations for several years since the early 2000s. I have advised some of that work from Oak Ridge National Laboratory (and later, in retirement) because of my interest in salmon responses to flow velocity. I have prepared reports and made presentations for Mr. Burns, who is a practicing construction company owner not accustomed to report writing. The debris connection is this: In 2008, the Natural Solutions' system was unexpectedly found effective in diverting high loads of woody debris as well as guiding salmon smolts. Nothing about the system was ineffective or inoperable because of the debris. In all years, the equipment was removed at the end of the study periods that lasted only several weeks during salmon smolt migrations. The success with debris deflection is now being applied and evaluated at water-intake locations [e.g., Burns, G., J. Johnson, C. Coutant, and M. Kosakowski. 2013. A test of the flow velocity enhancement system (FVES) for deflecting aquatic weeds from the intake of Genoa Station #3, Wisconsin. EPRI Report No. 3002001431, Palo Alto, California].

4) While NMFS's description of the bow wave is generally correct for water flow, it is not a sufficient description for particles with much mass (such as fish larvae or larger fish). That conclusion is a major point derived from the Alden flume studies. Particles with mass (even fish larvae) are ejected by the bow wave from the vicinity of the screen and inertia apparently keeps them from moving with the water toward the screen at the side of the cylinder. The bow wave is more than the null velocity point upstream of the nose cone; the null point is but one place in the region of changed velocities around an obstacle that defines the bow wave that affects deflection of the fish.

5) Milfoil mats drifting downstream might be a problem at CGS in future years, even though it has not been reported so far. Although some milfoil might stick onto the upstream end of the cylinder (nose cone) the plant material is likely to be diverted by the bow wave or washed off the porous sides by the high sweeping velocity.

6) Entrainment avoidance in the Alden flume studies clearly was a function of larval fish size, which was a combination of the fluid flow acting on larger body masses and increased swimming behavior by larger larvae that apparently reacted to the velocity discontinuities of the bow wave. Since the Chinook fry that NMFS is concerned about are

larger than the largest larvae studied in the Alden flume, they should, as stated, swim away.

A pronounced null point that might be used as a fish refuge is unlikely. The CGS screens have a fairly pointed leading end (shown in Figure 4 of the discussion paper), which minimizes the occurrence of a null point (zone of very low velocity) associated with a blunt cylinder.

7) NMFS is correct about eggs, but not fish larvae. Larvae of many species are quite good swimmers though they don't go far -- just far enough to stay away from the screen. The Alden flume tests provide abundant confirmation.

8) There are two issues raised here: One is that the NMFS non-consultation complaint is with NRC's analysis over the ESA listed species. These species are migrating from upstream. As the comment says, they are large enough not to be entrained by a 3/8ths inch pore size.

The second issue is with the non-ESA listed Chinook salmon fry (parr), and possibly steelhead parr, from Hanford spawning areas. The CGS intake screens are located in mid-river channel. This is generally not the habitat occupied by rearing Chinook fry, which forage along the shorelines. That was my personal experience when I was sampling juvenile Chinook in the Hanford Reach in the 1960s and confirmed by several monitoring studies since then. The shoreline feeding/rearing habitat is the main reason why stranding by fluctuating water elevation is such a concern there (many studies of that have been undertaken in the Hanford Reach). Nonetheless, the study by Dauble et al. found some Chinook parr at all depths in the reach of river near the 100-N reactor facility. The CGS field studies did identify some predatory fish around the intakes taking advantage of the lowered flow locations, but no salmon parr.

9) No baffle system was suggested for the CGS intake. The point made in the discussion paper was that young steelhead can and do detect an obstacle at some considerable distance upstream of it and move away, as demonstrated in my own research (which happened to use a baffle array as the obstacle). They most likely do so at the CGS intake.

10) NMFS is correct that the amount of observation to detect impingement has been small. And we agree that there is low likelihood of impingement. This can be attributed to low water velocities through the 3/8th-inch pores and the high sweeping velocities along the outside of the cylinders. The contention that small fish would have been entrained is not supported by the actual entrainment studies at CGS.

11) Figure 1 of the ENW report, which was a model study of the screen in the Alden flume, was shown for two purposes, one was to illustrate what happens to water flow at an example cylindrical screen, and the other to show what was actually studied at the Alden flume. From basic fluid dynamics, it would be generally representative of what happens to water flow at the CGS intake. Water flow does not equate to fish trajectory.

12) The scientific information available from fluid dynamics and biology support our conclusion of "little vulnerability" to entrainment and impingement even when juvenile salmon smaller than about 90 mm are present in the general vicinity. Most salmon fry are along shorelines not in the channel where the intake screens are located. Actual practice over nearly 30 years supports the conclusion. However, a modification of the screen could be made to essentially eliminate vulnerability according to NMFS criteria, but at what benefit for a large cost? That is an economic and political decision, not a scientific one. EPA has judged nationally that use of closed cycle cooling such as CGS is sufficient technology to minimize entrainment for non-ESA species.

13) Contrary to NMFS's assertion, debris does not accumulate on the screen, based on 28 years of operation.

14) We do not believe shallow depth during low river stage is an added vulnerability for salmon fry. As discussed in our report, the higher velocity over the screen at low river stage would act to more rapidly pass any fish over or around the screen rather than cause entrainment. The lateral line sensing would occur well upstream of the intake screen. As a real-life example, fish encountering a slightly submerged rock rarely wash over it and instead go around it.

15) The information in our report that is related this NMFS comment comes from a table presented in the initial NMFS comment letter. According to those NMFS data, the smallest sizes of young salmon near the CGS are still in the gravel and not yet in the water column and vulnerable to entrainment. The larger sizes listed in the table (migrants from upriver passing the CGS) are too large to be entrained in a 3/8th inch pore size (regardless of any behavioral responses). This limits the fish of concern for entrainment to a narrow range of fish sizes, which are known to occur near the CGS. For that narrow range of sizes, entrainment would be nearly precluded by the fluid dynamics around such a screen and behavioral avoidance, as shown in the Alden flume studies of fish larvae. These on-paper analyses are supported by actual experience over 28 years of CGS operation when entrainment has not been seen. Our report explored why there has been no (or little) actual entrainment; it was not predicting potential entrainment. Most of the NMFS hypotheticals are not supported by the actual performance results.

Appendix A

Review of Fish Screen Evaluation References Cited by NMFS: Relevance to The Columbia Generating Station In-River Intake Screens

Charles C. Coutant

Introduction

Correspondence by the National Marine Fisheries Service (NMFS) to The Washington Energy Facility Site Evaluation Council (NMFS August 6, 2013) and Energy Northwest (NMFS December 12, 2013) regarding NMFS's comments on the Columbia Generating Station's (CGS) intake screen for its cooling tower make-up water included memoranda from Bryan Nordlund, P.E. to NMFS Hydro Division (Nordlund July 31, 2013 and December 12, 2013, respectively). These memoranda referenced documents that NMFS felt important to their views and considered as evidence of NMFS's expertise with fish screens.

On request from Energy Northwest's Shannon Khounnala, NMFS provided Energy Northwest with electronic copies of most of the cited documents. A DVD disk was mailed that contained the July 31, 2013 documents; a zip file was sent with most of the December 12, 2013 documents, which was followed with a mailed DVD disk.

This appendix to Energy Northwest's responses to NMFS's December 12, 2013 correspondence evaluates the screen-evaluation studies that NMFS cites for their relevance for the CGS's in-river, screened intake. Unless otherwise noted, the studies are those referenced in the December 12, 2013 letter. Two cited references were not provided: Bigelow and Johnson 1996 (their 1995 study was sent instead) and Hosey and Associates and Fish Management Consultants 1990. The omissions are not believed important for these comments. Further background in NMFS's expertise with fish screens was found in an article by Nordlund (2008) that was obtained and read.

General Comments

The documents provided to Energy Northwest by NMFS show evidence of technical expertise primarily with angled rotary drum screens and associated fish bypasses. In a few cases the tested screens were bar or mesh screens oriented perpendicular to water flow or angled. These are not similar to the intake screen system at the Columbia Generating Station. The CGS uses cylindrical screens submerged parallel to the Columbia River flow in mid-channel. The hydraulic patterns of water flow past and into the two types of screens are not the same, particularly as they affect fish impingement, fish entrainment and debris problems.

A typical angled rotary drum screen and associated fish bypass are shown in Appendix Figure A-1. It is located where it blocks all water passing through the canal shortly downstream from the diversion dam across the source river. It is an active system requiring several motorized parts. Canal water and juvenile salmonids enter the facility through a trash rack, which stops large debris. The flow carries water and fish to an angled array of (in this case) 17 cylindrical screens whose axes are angled to canal flow. The screens are about 2/3 to ¾ submerged and they carry small debris over the top when rotated by a drive motor. With a sweeping flow along the screen faces being at least twice the velocity of water entering the screen, and a screen mesh size smaller than the fish, the fish are diverted along the array of screens by the sweeping flow. Fish exclusion depends strongly on the mesh size of the screen material and the amount of sweeping flow (which depends on the angle of the screen to canal water flow. The fish are funneled into bypass entrances and into a bypass channel. Some of the water entering the bypass is often pumped back into the canal after passing through vertical traveling screens to exclude fish. The concentrated fish in the bypass are diverted back to the river through return pipes. Some of the earlier screening facilities used static bar or mesh screens instead of the rotating screens but using the same general layout.

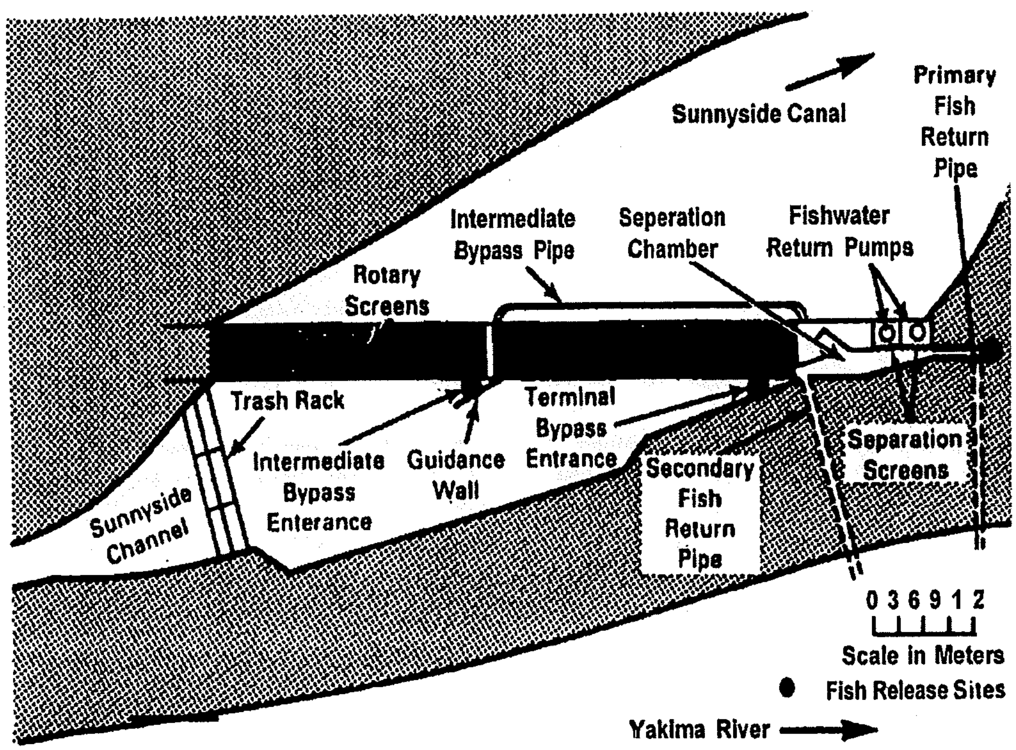

Figure A-1. Aerial view of the flow control structure and bypass system in the Sunnyside Canal Fish Screening Facility (Figure 3 from Neitzel et al. 1985).

This type of screen is described by a NMFS report (Nordlund 2008, Section 12.1, figures 12.1 and 12.2). It is widely used on irrigation canals in the Pacific Northwest.

In contrast, the CGS in-river intake screens are passive, perforated cylinders with river water flowing over, under, and around the cylinders. As described in the main text, the hydraulic pattern around the cylinder, initiated by flow separation at the front cone (bow wave), tends to move fish away from the screen surface. This hydraulic pattern was the primary mechanism for exclusion of fish larvae from the screen openings in detailed laboratory flume studies ("hydraulic bypass"). The hydraulics operates on both living and dead material approaching the screen, which prevents buildup of screen-clogging debris. Fish are likely to detect and avoid the cylinder's disturbed flow and pass around the cylinder (the second most prominent mechanism in the flume studies).

In a review of water intake screens, Nordlund (2008; not provided by NMFS) briefly introduces a design similar to that at the CGS as one type of Pump Intake Screens (Section 12.8, Figure 12-8). He states that it is for use in a "pressurized system", which the CGS is not. He states that it is appropriate for "small pump intake screens" for "small irrigation diversions." Although Nordlund (2008) stresses biomechanics (mostly swimming speed) and hydraulics (e.g., flow vectors at an angled screen face) for all screen evaluations, there is no discussion of these factors for pump intake screens oriented parallel with the river flow, which is the case at CGS.

Other agencies or organizations conducted the screen-evaluation studies provided by NMFS as evidence of NMFS' general fish-screen expertise. The Bonneville Power Administration funded many of the studies. Any involvement by NMFS in the studies is unclear from the reports.

Detailed Comments by Study

Anonymous. 1994. Dryden Screens Fisheries Evaluation Data Summary. National Marine Fisheries Service? (from August 6, 2013 NMFS letter)).

This very informal report indicated that it evaluated "angle rotary drum screens" in use in the Yakima River Basin. The screen for this summary was not described. However, it is stated that salmonid fry were vulnerable to passage through "the 1/8-inch profile bar screens." The screens passed "~225 cfs" and there was a "bypass flow" of 20 cfs.

This report is inconsistent with Mueller et al. (1995) in its categorization of the Dryden fish screens. This report refers to the Dryden screens as "angle rotary drum screens" whereas Mueller et al., presumably studying the same screen system, refers to them as "fixed plate vertical profile bar screens." The reference to "1/8-inch profile bar screens" in this anonymous report suggests that the author was unsure of the type of screen being evaluated. This inconsistency renders this informal report unreliable. See comments on Mueller et al. (1995) for a more thorough report on the Dryden screens.

Bates, K., and R. Fuller. 1992. Salmon fry screen mesh study. State of Washington, Department of Fisheries, Habitat Management Division, Olympia, Washington. (from August 6, 2013 letter).

This study tested three basic types of screen material to determine the screen opening and bar orientation needed to preclude passage of salmon fry. The intended application was to preclude (100% exclusion) salmon fry from entering irrigation ditches. Fish were tested in flumes at two hatcheries. **Screens of various types and mesh sizes were placed in the flumes perpendicular to water flow** to obstruct downstream passage (report's Figure 1). The screens tested would be considered **vertical fixed plate screens** of Nordund (2008) although their placement was simply in a test flume. Test fish were introduced upstream of each test screen and collected both upstream and downstream of each test screen. Water flow was directly toward and through each screen with no fish escape possible from the introduction chamber other than through the screen. The study tested six mesh sizes or configurations of profile bar screens, five sizes of wire mesh screens, and three sizes of perforated plate screens. Chinook fry were tested (mean fork length 37.0 mm SD 1.35) as well as sockeye and chum fry.

The test configuration was completely different from the screens at the CGS. There was no sweeping flow to counteract the water flow through the screen openings. Although the study tested perforated plate screens, the orientation of the screen material to water flow (and therefore the hydraulic pattern) was inconsistent with the CGS screens. Thus, this study has little relevance to a performance evaluation of the CGS screen.

Beecher, H. 1993 (draft). Screen mesh evaluation for water diversions. Washington Department of Game, Olympia, Washington. (from August 6, 2013 letter).

NMFS provided a draft report copy of a study that tested various screen materials for their exclusion of rainbow trout and steelhead fry in a test flume similar to that used by Bates and Fuller (1992). Some of the same screens were used. The application was, as for Bates and Fuller (1992), total exclusion of fry from irrigation ditches. It is not known if the report was ever finalized.

As for the Bates and Fuller (1992) study, the test configuration was inconsistent with an evaluation of the CGS screens, which are of a fully different design and orientation.

Bigelow, J. P. 1995. Survival and condition of juvenile salmonids passing through the downstream migrant fish protection facilities at Red Bluff Diversion Dam on the Sacramento River, spring and summer 1994. U.S. Fish and Wildlife Service Annual Report. Northern Central Valley Fish and Wildlife Office, Red Bluff, California

This study is not relevant to evaluation of the CGS intakes. It was a study of fish injury and survival in passage through the fish bypass system of the Red Bluff Diversion Dam. It was not a screen study. The fish bypass transports fish screened from the Sacramento River water entering the Tehama Calousa Canal and returned to the river. The screens are **rotary drum screens** but were not part of the study. Test fish were introduced directly into the 122 cm conduit at bypass entrances and collected after bypass passage.

Hosey & Associates. 1988 (Draft). Evaluation of effectiveness of fish protection facilities. Chandler facility evaluation. Prepared for Bureau of Reclamation

Contract No. 7-CS-10-07720 by Hosey & Associates Engineering Company and Fish Management Consultants.

This study evaluated a (then) new design of **angled rotary drum screens** unlike the screens at the CGS. It evaluated a new fish screening facility at the Chandler Canal located approximately one mile downstream of the Prosser Diversion Dam at River Mile 47.1 on the Yakima River, Washington. The new fish screens were situated at an angle to the canal flow and equipped with a fish bypass to return juvenile salmon to the Yakima River. The report commented on the old fish screens, which were also rotary drum screens but were situated perpendicular to the water flow. Flow perpendicular to the screens, a 2 ft/s approach velocity and no sweeping flow caused poor diversion to the fish bypass and high fish mortalities. The new screen included more rotary modules placed at an angle to canal flow (17.5°), 1/8-inch screen mesh, a lower approach velocity (<0.5 fps) and a sweeping flow (2 times the approach velocity). Multiple bypass entrance portals were also included to reduce the time fish were exposed to the screens. The study indicated that the facility effectively screened juvenile salmon and returned them to the Yakima River with minimal injury (0% descaling of fall Chinook). Debris load increased descaling, however. Tests indicated no (or very low) "leakage of fish through or over the screens and into the irrigation canal."

Despite being a good study that demonstrated the efficacy of a design that was superior to the old Chandler screens, the study is not directly relevant to the type of screen at the CGS. It did show the high value of a sweeping flow derived from the angled screens (accentuated in the CGS screens that are parallel with river flow) and low approach velocity of 0.5 fps (met by the CGS screens).

Hosey & Associates. 1990. Evaluation of effectiveness of fish protection facilities. Evaluation of the Chandler, Columbia, Roza and Easton screening facilities. Completion Report. Prepared for Bureau of Reclamation Contract No. 7-CS-10-07720 by Hosey & Associates Engineering Company and Fish Management Consultants.

This study extended the 1988 study by the same authors to three other **angled rotary drum** screening facilities that were unlike the in-river intake facility at the CGS. As with the Chandler facility (Hosey & Associates 1988) the other three were on the Yakima River. The Easton and Roza facilities were at the Easton Diversion Dam and Rosa Diversion Dam, both upstream of the Chandler facility. The Columbia Screening Facility was at the Horn Rapids Dam downstream of Chandler. All screens met the then Washington State juvenile screening criteria of 0.5 fps approach velocity and a sweeping velocity at least twice as great as the approach velocity. The similar screen designs were effective in bypassing fish with low levels of injury (<1%) for both fry-sized and smolt-sized fish. Proper fitting of the rotating screens was demonstrated to be important. There was no leakage of fish observed at Chandler, Columbia or Roza facilities, but leakage of fish past the bottom seals appeared to account for most or all of spring Chinook fry and juveniles not bypassed at Easton. Predation by birds was observed at the exit of the fish return and predatory northern pikeminnow (then called squawfish) were found in the canal approach and bypass outlet at Chandler.

As for the study of only Chandler (Hosey & Associates 1988 draft), these studies were valuable assessments of the angled rotary drum screens but not directly relevant to the CGS in-river screens.

Johnsen, R. C. 1995. Fish passage evaluation tests in the north shore fishway hydroelectric project at The Dalles Dam. Prepared for Northern Wasco County People's Utility District, The Dalles, Oregon.

This study is not useful for comparison with the CGS in-river intake screens because the type and location of screens are not given. It was a salmonid smolt passage study conducted at the intake channel of the North Shore Fishway Hydroelectric project (NSFHP). The NSFHP is a generation project of the Northern Wasco County People's Utility District at The Dalles Dam that uses water from the original fishway auxiliary water supply system to drive a turbine before returning the flow to the lower sections of the fishway. The report notes a "screened intake channel" but gives no details of the type of screen or its placement.

Knapp, S. M, editor. 1992. Evaluation of juvenile fish bypass and adult fish passage facilities at water diversions in the Umatilla River. Annual and Interim Progress Reports October 1990 – September 1991. Prepared for Bonneville Power Administration, Portland, Oregon by Oregon Department of Fish and Wildlife and Confederated Tribes of the Umatilla Indian Reservation. Project No. 89-024-01, Contract No. DE-BI79-89BP01385.

This report is of little relevance to the CGS in-river intake. It is a combination of separate annual reports by various authors of plans for, and studies of, the juvenile fish screen and bypass system and adult passage at the West Extension Irrigation District Canal at Three Mile Falls Dam in the Umatilla River. Additionally, one report also described plans for studies of the Maxwell and Westmorland dams, also on the Umatilla River.

The main fish screens were **angled rotating drum screens** that are unlike the in-river screens at the CGS. A pumpback well contained a conventional vertical traveling screen, also unlike the CGS intake screens. The report provided no details about the screens beyond a generalized schematic layout of the canal, screens, and bypass. Results of extensive fish testing were not related to screen parameters such as pore size, approach velocity, or sweeping velocity. Fall Chinook salmon fry were among the salmon fry and smolts used in testing. Some screen leakage of fall Chinook fry around the screens was observed. The drum screen array was 99.8% efficient in screening fall Chinook salmon fry from the canal. While useful for evaluating performance of drum screens, these studies have little relevance for evaluating entrainment at the CGS intake.

Knapp, S. M., editor. 1994. Evaluation of juvenile fish bypass and adult fish passage facilities at water diversions in the Umatilla River. Annual Report 1993. Report to

the Bonneville Power Administration by Oregon Department of Fish and Wildlife and Confederated Tribes of the Umatilla Indian Reservation, Contract No. 1989BP01385, Project No. 198902401. BPA Report DOE/BP-01385-4.

This is a continuation report that extends the information in Knapp (1992) through September 1993 concerning evaluations of juvenile fish passage facilities at Three Mile Falls, Maxwell, Westland, and Feed Canal dams on the Umatilla River, Oregon. Screens were all **angled rotary drum screens**, some with **vertical traveling screens** at pumpback wells, with some site-specific modifications. Evaluation of these technologies through extensive fish testing has little relevance for the in-river, cylindrical screens used at CGS. Notably, this report includes consideration of screen velocity parameters, which varied with water depth and along the screen arrays.

The rotary drum screens at all facilities were constructed of stainless steel wire cloth with approximately 0.125-inch-square mesh openings. Numbers and dimensions of drum screens at each site were designed to provide adequate screen surface area to meet water velocity criteria at maximum design canal flows based on 1990 criteria. All screens were operated in accordance with standard operating criteria developed by NMFS (provided in an appendix).

Approach velocities at the Westland Canal drum screens were generally within criteria, but were not uniform with depth (highest at 80% depth) or along the drum array (highest near bypass entrances). Sweep velocities also varied across the screens (lowest at 80% depth). Despite the differences in velocities, the efficiency of the Westland Canal screens for preventing passage of fry ranged from 99.81% to 100%. Approach and sweep velocities at the traveling screens were generally within criteria and no fish were entrained.

The Maxwell Canal drum screens showed approach velocities within criteria for fingerlings but not for fry. Approach and sweep velocities at this screen facility were also not uniform through the water column or between screens.

At the Feed Canal, approach velocities exceeded criteria for salmonid fry and fingerlings in 80% and 42% of the sampling locations, respectively, when water depth was 1.5 ft below normal operating depth. Approach velocities were highest at 60% of depth and at screens closest to the bypass entrances. Sweep velocities generally exceeded 1 fps except at the upstream screen were it was 0.27 fps.

Although the reports provide results of extensive and well-conducted fish passage experiments in each of the drum-screen and bypass facilities they are not relevant to the type and location of the intake screen facility at the CGS.

Mueller, R. P., D. A. Neitzel, and C. S. Abernathy. 1995. Fisheries Evaluation of the Dryden Fish Screening Facility. Annual Report 1994. Report by Pacific Northwest Laboratory, Richlnd, Washington for Bonneville Power Administration, Portland, Oregon. Project No. 1985-06200, BPA Report DOE/BP-00029-2.

This report provides evaluations of the effectiveness of the Dryden screening facility for intercepting and returning salmonids unharmed to the Wenatchee River. Constructed in 1993 according to then-WDFW screening criteria, the Dryden facility was located in the Wenatchee Reclamation District Canal near Dryden in north central Washington State. It was in the canal downstream of the Dryden Dam on the Wenatchee River (report's Figure 2). The Bonneville Power Administration selected it for passage improvements under the Columbia River Fish and Wildlife Program. The National Marine Fisheries Service was responsible for establishing written criteria for operation of the facility.

The Dryden screen evaluated in this study consisted of seven **fixed plate vertical profile bar panels** installed angled sharply downstream at a 15° angle to flow (report's Figure 3). Openings in the profile bar were 3.17 mm (0.125 in) wide. The downstream end of the screen was provided with a fish bypass slot leading to a bypass flume and pipe that returned fish to the Wenatchee River (report's Figure 3).

This fixed-plate screen with vertical profile bar panels is entirely different from the cylindrical screen oriented with river flow at the Columbia Generating Station. NMFS is familiar with vertical bar screens (Nordlund 2008, Section 12.2). It is described as the "second most widely used type of positive barrier juvenile fish screen" in the Pacific Northwest. It requires a mechanical cleaning system for debris removal. Examples are illustrated in the Nordlund's figures 12-3 and 12-4. Experience with this type of screen would not be relevant to the CGS screens.

Neitzel, D. A., C. S. Abernathy, E. W. Lusty, and L. A. Prohammer. 1985. A fisheries evaluation of the Sunnyside Canal Fish screening Facility, Spring 1985. Annual Report. Prepared for Bonneville Power Administration, Portland, Oregon by Pacific Northwest Laboratory, Richland, Washington. BPA Report DOE/BP-01830-1.

This report discusses results of a fisheries evaluation of the efficacy of the then-new (completed Spring 1985) **angled rotary drum** screening facility on the Sunnyside Canal. The screening facility bears no resemblance to the CGS in-river intake screens and the report is thus of little value for evaluating the CGS screens.

The Sunnyside Canal diverts water from the Yakima River at the Sunnyside Dam and the screening facility returns fish that enter the canal to the river. Steelhead and spring Chinook salmon smolts from hatchery sources (no Chinook salmon fry) were tested with experimental fish releases and recaptures. Some native migrants were also assayed for descaling. The screens are angled (26° to canal flow) rotary drum screens with a fish bypass of a type being installed at numerous irrigation diversions under Bonneville Power Administration funding. During normal operation (the only condition tested) the approach velocity is said to be less than 0.014 m^3/sec (0.046 ft/sec) and the sweeping flow greater than 0.057 m^3/sec (0.187 ft/sec). The report concluded that smolts passed successfully with little descaling.

Neitzel, D. A., C. S. Abernathy, and E. W. Lusty. 1990. A fisheries evaluation of the Westside Ditch and Wapato Canal fish screening facilities, Spring 1989. Annual Report. Report for Bonneville Power Administration, Portland, Oregon by Pacific Northwest Laboratory, Richland, Washington. BPA Report DOE/BP-01830-8.

This study evaluated the efficacy of new **angled rotary drum screens** at two screening and fish-bypass facilities on the Yakima River, the Westside Ditch and Wapato Canal. The screen facilities were the standard design for BPA-funded screen replacements and unlike the in-river screens at the CGS. Screens were angled 26° to canal flow. Screen mesh openings were 3.2 mm (1/8 inch). The maximum approach velocity was 0.15 m/s (0.5 fps). Sweeping velocity to approach velocity ratio was equal to or exceeded 2:1.

Spring Chinook salmon and steelhead smolts were experimentally passed through the screening facilities. Rainbow trout fry were used at the Westside Ditch screens. At Wapato, the screens prevented most fish from entering the canal behind the screens. At Westside Ditch, 0-age fry were able to pass through, over or around the screens (6 and 25% passed into the canal for trout fry and Chinook fry, respectively).

The report has little relevance for evaluating the CGS in-river intake screens due to the large differences in design and location.

Nigro, A. A., editor. 1990. Evaluation of juvenile fish bypass and adult fish passage facilities at Three Mile Falls Dam, Umatilla River. Report for Bonneville Power Administration, Portland, Oregon by Oregon Department of Fish and Wildlife and Confederated Tribes of the Umatilla Indian Reservation. Project No. 89-024-01, Contract No. DE-B179-89BP01385.

This document contains two study reports of progress between October 1989 through September 1990, one for evaluation of the juvenile bypass at the **angled rotary drum screen** facility in the West Extension Irrigation District canal at Three Mile Dam on the Umatilla River and one examining adult salmonid passage at the same dam. Natural-run out-migrating fish were sampled in the bypass of the screen facility. Both resident species and salmonids (yearling and subyearling Chinook, coho and summer steelhead smolts) were enumerated and checked for descaling. Screen mesh size was not given. Approach (0.04-0.66 fps) and sweeping (0.25-1.12 fps) velocity measurements were lowest at low canal flows. The bypass effectively passed fish although some juvenile salmonids passed the screens by unknown routes. Debris and headgate operation were problems.

This study provided a good early evaluation of the rotary drum screen and bypass system at this site, which led to recommendations for better operational procedures and additional study (additional studies were reported in Knapp 1992 and 1994). The facility bears no resemblance to the CGS in-river intake screens, however, so is of little use for evaluating the CGS system.

Page, T. L., D. A. Neitzel, and R. H. Gray. 1977. Comparative fish impingement at two adjacent water intakes on the Mid-Columbia River. Report PNL-SA-6606, Battelle Pacific Northwest Laboratories, Richland, Washington. (from August 6, 2013 letter).

This report evaluated fish impingement at two adjacent water intakes on the Columbia River on the Hanford Reservation. One intake was for the U.S. Department of Energy's 100-N reactor; the second was the Hanford Generating Station (HGP), which use steam from the 100-N reactor to produce electricity. The 100-N water intake was about 276 m (905 ft) downstream of the HGP intake.

Both intakes used **vertical traveling screens.** Each screen consisted of a vertical row of panels with 0.32 cm (1/8 in) square openings (report's Figure 4). The panels are rotated vertically around axels at the top and bottom of the screen system using an electric motor. The screens had similar through-screen water velocities. Trash and impinged fish are carried to the top of the rotating screens, washed into a sluiceway, and returned to the river via a sump pit. Previous studies at HGP indicated that over 90% of fish impinged were zero-age Chinook salmon, likely from local spawning beds (Gray et al. 1975; Page et al. 1975, 1976). Gray et al. identified passage through openings between screen panels, along the sides and bottom of the screens as causing entrainment. These entry points were sealed before the studies in this report.

NMFS is familiar with vertical traveling screens, and is illustrated in the report by Nordlund (2008; Section 12.3; Figure 12-5). Nordlund notes that panel-type vertical traveling screens were not specifically manufactured for fish protection and old installations show high incidence of impingement and entrainment.

The vertical traveling screens studied in this report were unlike the cylindrical screens used at the CGS in both configuration and location with respect to the river. Water flows directly into the screen face without sweeping flow. Fish have no escape from impingement (or entrainment) other than swimming away from the screen. Furthermore, the intakes are along the shoreline where Chinook salmon fry forage and indented (especially the 100-N intake) making egress for salmon fry difficult. In contrast, the CGS screens are in the river channel where they experience high sweeping flows. Experience with vertical traveling screen at a shoreline intake is not relevant to evaluations of the CGS intake screens.

Ruehle, T. E., and C. S. McCutcheon. 1994. Pit-tag studies with juvenile salmonids at the Chandler Canal Fish Collection Facility, Yakima River, 1990. Report for Bonneville Power Administration, Portland, Oregon by Northwest Fisheries Science Center, National Marine Fisheries Service, Seattle, Washington. Project No. 90-65, Contract No. DE-AI79-90BP07099. BPA Report DOE/BP-07099-1.

The study evaluated the suitability of using PIT tags to evaluate fish return to the Yakima River by the screening and bypass facility at the Chandler Canal. No details of the type of screen were presented. Thus, the report is not useful for evaluating the CGS screens.

Appendix References

NMFS (National Marine Fisheries Service). Letter to Jim La Spina, Washington Energy Facility Site Evaluation Council from Bruce Suzumoto of NMFS, with attached July 31, 2013 Memorandum to Hydro Division Files from Bryan Nordlund.

NMFS. December 12, 2013. Letter to Shannon Khounna, Energy Northwest from Michael P. Tehan of NMFS with attached December 12, 2013 Memorandum to Ritchie Graves from Bryan Nordlund.

Nordlund, B. 2008. Designing fish screens for fish protection at water diversions. National Marine Fisheries Service, Lacy, Washington.